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ABUNDANCE AND LIFE HISTORY OF NATIVE AND INTRODUCED EARTHWORMS (*ANNELIDA: MEGASCOLECIDAE* AND *LUMBRICIDAE*) IN PASTURE SOILS IN THE MOUNT LOFTY RANGES, SOUTH AUSTRALIA

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Summary

BAKER, G. H., BARRETT, V. J., GREY-GARDNER, R. & BUCKERFIELD, J. C. (1993) Abundance and life history of native and introduced earthworms (Annelida : Megascolecidae and Lumbricidae) in pasture soils in the Mount Lofty Ranges, South Australia *Trans. R. Soc. S. Aust.* 117(1), 47-53, 4 June, 1993.

Seasonal abundance of the native earthworm, *Gemascolex walkeri* (Megascolecidae), and introduced earthworms, *Aporrectodea rosea* and *Octolasion cyaneum* (Lumbricidae), was monitored in three pastures in the Mt Lofty Ranges, South Australia. Highest numbers of earthworms were recorded in late winter and early spring. Densities of up to 108, 32 and 96 m^{-2} were recorded for *G. walkeri*, *A. rosea* and *O. cyaneum* respectively.

All three species of earthworms occurred predominantly in the top 10 cm of soil for four to five months per year (autumn to spring), when soils were wettest. During other seasons, they were found lower in the soil profile. Distributions within pastures were patchy and could, in some cases, be explained by soil type *(A. rosea)* and soil moisture *(G. walkeri)*.

Although introduced species of earthworms generally predominate in pastures in southern Australia, native species such as *G. walkeri* can occasionally constitute a substantial proportion of the total earthworm population.

KEY WORDS: Earthworms, Megascolecidae, Lumbricidae, pastures, South Australia, depth profile, life history.

Introduction

Australia has a rich native earthworm fauna, dominated by the Megascolecidae (Jamieson 1981). However, information on the life histories, distributions and abundances of these native species and the factors influencing them is scarce (Wood 1974; Jamieson 1981; Abbott *et al.* 1985; Baker *et al.* 1991, 1992a). The distributions of introduced species in Australia (e.g. Lumbricidae), are better understood (Abbott 1982, 1985; Abbott & Parker 1980; Tisdall 1985; Kingston & Temple-Smith 1989; Baker *et al.* 1991, 1992a), and there have been some studies of their life histories and population dynamics (Barley 1959a; Tisdall 1985; Rovira *et al.* 1987; Kingston 1989; McCredie *et al.* 1992; Baker *et al.* 1992b). The influence of earthworms, either native or introduced, on soil structure and fertility in Australia has received little study (Barley 1959b,c; Barley & Jennings 1959; Abbott & Parker 1981). Increased knowledge of the ecology and functional importance of the resident communities of earthworms in Australian soils will assist in developing improved management strategies that may lead to increased plant production and help reduce soil degradation (Baker 1989a,b).

Baker *et al.* (1992b) demonstrated the seasonal abundances and depth profiles of two introduced species, *Aporrectodea trapezoides* and *A. caliginosa* (Lumbricidae), in five permanent pastures in South Australia. *A. trapezoides* and *A. caliginosa* were active and abundant in the root zone for three to seven months, from autumn to spring, when soil moisture was highest. Mature adults were present from mid-winter to mid-spring. Patchy distributions of both species were found within some of the pastures and were partly explained by variation in soil type.

This paper reports the seasonal abundances, life histories, lateral and vertical distributions and species associations of native and introduced earthworm species that were found together with the more abundant *A. trapezoides* and *A. caliginosa* at three of the pasture sites sampled by Baker *et al.* (1992b).

Materials and Methods

Three permanent pastures in the Mt Lofty Ranges, South Australia were sampled for earthworms each month from March 1990 until November 1990 (Tungkillo) or January 1991 (Birdwood and Parawa). The climate of the region is Mediterranean, with cool moist winters and hot dry summers. Mean annual rainfall varied between sites (Tungkillo, 575 mm; Birdwood, 750 mm and Parawa, 900 mm) as did soil type (Tungkillo, uniform sand [Uc1.4]; Birdwood, yellow and black duplex soils [Dy3.4 and Dd1.1] and Parawa, yellow duplex soil [Dy2.2]) (Northcote 1979). The yellow and black duplex soils are Palexeralfs and the uniform sand is a Quartzipsamment in the US Soil Taxonomy (Soil Survey Staff 1987). Baker *et al.*

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(1992b) provide further information on chemical and physical properties of the soils at each site.

At each site, soil samples were taken within a 50 × 50 m plot that was divided into five 10 m wide strips. Each month, three random samples were taken within each strip at Tungkillo and Birdwood and two samples were taken within each strip at Parawa. Each sample was $0.1m^2 \times 30$ cm deep. The samples were separated into three depths, 0-10 cm (within which the majority of plant roots occurred), 10-20 cm and 20-30 cm. The soil was hand-sorted for earthworms and cocoons which were preserved in 70% ethanol.

Approximately 400 g of soil were collected from the 0-10 cm layer in one sample from each strip for gravimetric moisture determination. These soil samples were collected every month except March 1990. Curves relating matric suctions of soil water to gravimetric water content were calculated for the soils at each of the three sites using the filter paper method (Greacen *et al.* 1989). This enabled comparisons of soil moisture availability between sites.

Species were identified within two weeks of collection, using the keys in Jamieson (1974) and Sims & Gerard (1985). Worms were separated into juveniles (no genital markings), subadults (with genital markings but no mature clitellum) and adults (with mature clitellum).

Two soil types (yellow and black duplex soils) occurred within the plot at Birdwood. The distributions of these soils were mapped by taking 25 regularly spaced auger samples (each 3 cm wide × 50 cm deep) within the plot and supplementing these with additional samples where the soil boundaries were unclear. There were no obvious spatial variations in soil type within the other two plots.

The regular sampling at Tungkillo indicated that soil moisture varied markedly within the plot, being highest near the centre and eastern edge. This pattern was possibly related to the drainage characteristics of the site, the moistest soil being found in the lowest lying areas within the plot. To check this perceived pattern in soil moisture, 22 auger samples (10 cm in diameter) were taken at random co-ordinates throughout the plot during March 1991, soil being collected from 0-10, 10-20, 20-30, 30-40 and 40-50 cm below the surface. Gravimetric soil moistures were determined for each depth.

Results

Abundance and Life History

Data for the seasonal abundance and life history of three earthworm species that were commonly collected at Tungkillo, Birdwood and Parawa are given in Figs 1 and 2. Similar data for rarer populations of these and other species found at the three sites are given in Table 1.

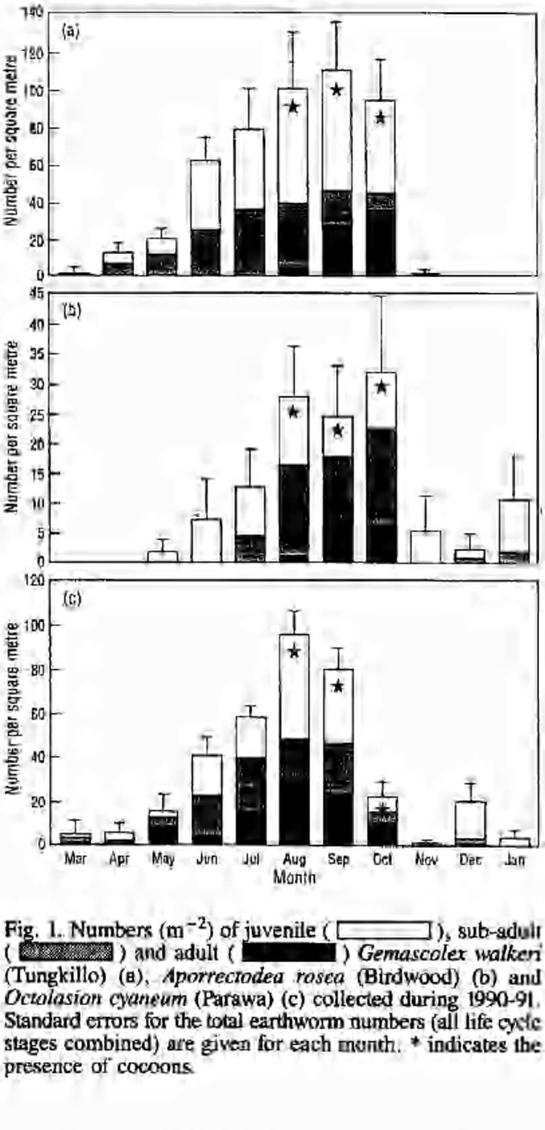

Fig. 1. Numbers (m^{-2}) of juvenile ( ), sub-adult ( ) and adult ( ) *Gemascolex walkeri* (Tungkillo) (a), *Aporrectodea rosea* (Birdwood) (b) and *Octolasion cyaneum* (Parawa) (c) collected during 1990-91. Standard errors for the total earthworm numbers (all life cycle stages combined) are given for each month. * indicates the presence of cocoons.

Gemascolex walkeri Jamieson (Megascolecidae) was common at Tungkillo, not found at Parawa and occurred in only negligible numbers at Birdwood (Fig. 1, Table 1). *Aporrectodea rosea* (Savigny) (Lumbricidae) was most common at Birdwood and was also found at Tungkillo. *Octolasion cyaneum* (Savigny) (Lumbricidae) was found at Parawa but not at the other two sites. The abundances of *G. walkeri*, *A. rosea* and *O. cyaneum* varied between months (Kruskal-Wallis H = 54.9, $p < 0.001$ for *G. walkeri* at Tungkillo; H = 42.3, $p < 0.001$ for *A. rosea* at Birdwood; H = 45.1, $p < 0.001$ for *O. cyaneum* at Parawa), with highest numbers found from late winter to early spring (August to September or October) (Fig. 1). Other species were generally recorded in low numbers at the three sites (Table 1). *Gemascolex lateralis* (Spencer)

(Megascolecidae) was abundant at parawa in May and June 1990 (Table 1), but most of the individuals of this species collected then were found in only one sample in each month (53% of the total collection in May and 69% in June). There was no significant variation between months in the abundance of *G. lateralis* at Parawa ($H = 8.6$, $p > 0.05$).

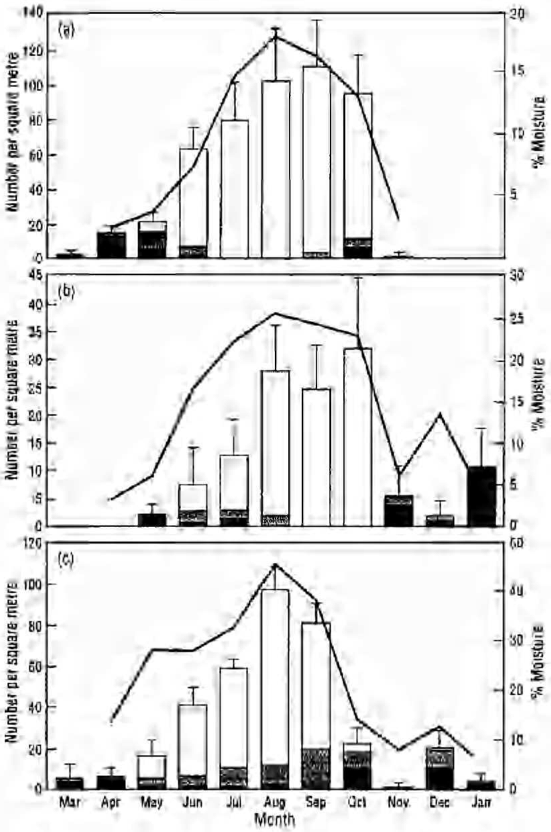

Fig. 2. Numbers (m^{-2}) of *Gemascolex walkeri* (Tungkillo) (a), *Aporrectodea rosea* (Birdwood) (b) and *Octolasion cyaneum* (Parawa) (c) collected 0-10 cm ( ), 10-20 cm ( ) and 20-30 cm ( ) below the soil surface during 1990-91. Standard errors for the total earthworm numbers (all depths combined) are given for each month. Mean gravimetric soil moistures for 0-10 cm deep are also indicated for each site (line).

Adults of *G. walkeri* and *A. rosea* were mostly collected in early spring (Fig. 1). Adults of *O. cyaneum* were present on most sampling occasions.

Earthworm cocoons were found at all three sites, during each month from July to October (up to 39 cocoons per soil sample).

Virtually all the cocoons (> 99%) were found in the top 10 cm of soil. The identity of these cocoons is unknown. Most of the cocoons probably belonged to *Aporrectodea trapezoides*, the most abundant species at these sites (Baker *et al.* 1992b). However, the breeding seasons of all species can be regarded as occurring within these months.

Depth Profile

G. walkeri, *A. rosea* and *O. cyaneum* occurred mainly in the root zone (0-10 cm depth) for four to five months during autumn to spring, when soils were wettest (Fig. 2) (Pearson $r_8 = 0.98$, $r_{10} = 0.86$ and $r_{10} = 0.94$ for soil moistures and numbers of *G. walkeri* (Tungkillo), *A. rosea* (Birdwood) and *O. cyaneum* (Parawa) respectively at 0-10 cm depth; $p < 0.01$ in all cases). Earthworms became more common in the root zone compared with lower depths during May or June and less so in October or November.

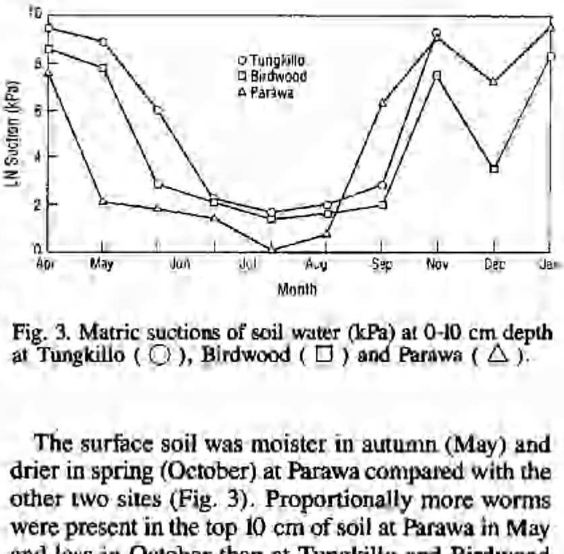

Fig. 3. Matric suctions of soil water (kPa) at 0-10 cm depth at Tungkillo (○), Birdwood (□) and Parawa (△).

The surface soil was moister in autumn (May) and drier in spring (October) at Parawa compared with the other two sites (Fig. 3). Proportionally more worms were present in the top 10 cm of soil at Parawa in May and less in October than at Tungkillo and Birdwood (Fig. 2, Table 1) (comparing the total earthworm numbers at 0-10 cm and 10-30 cm depth at each site for all species included in Table 1 and Fig. 2, $\chi^2 = 70.65$, $p < 0.001$ and $\chi^2 = 96.91$, $p < 0.001$ for May and October respectively).

Distribution Within Plots

The distributions of some species at each of the three sites were patchy. At Birdwood, *A. rosea* was most common in the south-eastern corner of the plot whilst *Gemascolex lateralis* and *G. stirlingi* occurred predominantly in the north-eastern corner (Fig. 4). The distribution of *A. rosea* approximated that of the black duplex soils at Birdwood (Fig. 4) ($\chi^2 = 16.25$, $p <$ 0.001 where the samples with and without *A. rosea*

TABLE 1.
Numbers of earthworms collected in low numbers at three pasture sites in the Mt Lofty Ranges, South Australia. Numbers in parentheses are for earthworms in the top 10 cm of soil, * indicates adults were present and – that no samples were taken.

Species	Month											
	M	A	M	J	J	A	S	O	N	D	J	Total
Aporrectodea rosea												
Tungkillo	3	2	26 (7)	2	6 (6)	4* (4)	1* (1)	6* (6)	10* (3)	–	–	60
Microscolex dubius												
Tungkillo						4* (4)	14* (14)	8* (8)		–	–	26
Birdwood						2* (2)						2
Parawa							1* (1)					1
Gemascolex stirlingi												
Tungkillo					4* (2)	·1				–	–	5
Birdwood	1	1	3*	1	6 (5)	1	2 (1)	1	1	2	1	20
G. lateralis												
Tungkillo					1 (1)					–	–	1
Birdwood	5		4*	1 (1)	4 (4)	10 (10)	3 (3)	1 (1)	2	3		33
Parawa	3	6	53* (53)	78* (78)	17* (17)	14* (14)	9* (9)	3* (1)	21*	6*	19*	229
G. walkeri												
Birdwood							3* (3)			3		6
Native W												
Tungkillo		1*		1 (1)		1 (1)	1 (1)	2 (2)		–	–	6
Native J												
Birdwood									11*			11

within the areas with yellow and black duplex soils were compared), but the distributions of the two *Gemascolex* spp. could not be explained by variation in soil type.

At Tungkillo, *G. walkeri* was most abundant near the centre and eastern end of the plot (Fig. 5a) (χ^2 = 31.29, $p < 0.001$ where the frequencies of samples with 0, 1-5, 6-10 and > 10 earthworms inside and outside the area in Fig. 5a were compared). The soil within the area where *G. walkeri* was most common was moister in late summer than the soil outside it (Table 2). During the wettest months of the year, the same trend was also apparent. Mean soil moistures for the samples taken at 0-10 cm depth during the routine monitoring at Tungkillo from July to October 1990 were 17.2% (where *G. walkeri* was most common) and 13.1% (elsewhere) ($t = 2.23$, $p < 0.05$).

G. lateralis was mostly found in the south-eastern corner of the plot at Parawa (Fig. 5b) (χ^2 = 62.05, $p < 0.001$ where the frequencies of samples with 0, 1-5 and > 5 earthworms inside and outside the shaded area in Fig. 5b were compared). There was no obvious variation in habitat within the plot that might explain this patchiness in *G. lateralis*. However, several *Eucalyptus* trees bordered the plot adjacent to the area where *G. lateralis* was found. Perhaps these remnants of natural vegetation are responsible for local survival of this native earthworm.

Discussion

The life histories, patterns in seasonal abundance and depth profiles of *G. walkeri*, *A. rosea* and *O. cyaneum* in pastures in the Mt Lofty Ranges, South Australia are broadly similar to those reported previously for *A. trapezoides* and *A. caliginosa* (Baker *et al.* 1992b). Earthworm activity in the pasture root zone (0-10 cm depth) is mostly restricted to winter and early spring when soils are wettest. Adult earthworms are most commonly found in late winter-early spring, but for some species (e.g. *O. cyaneum* and *G. lateralis*), adults can be found during most months of the year.

The proportions of *A. rosea*, *O. cyaneum* and *Gemascolex* spp. populations that survive summer are not known, but many of these earthworms have been

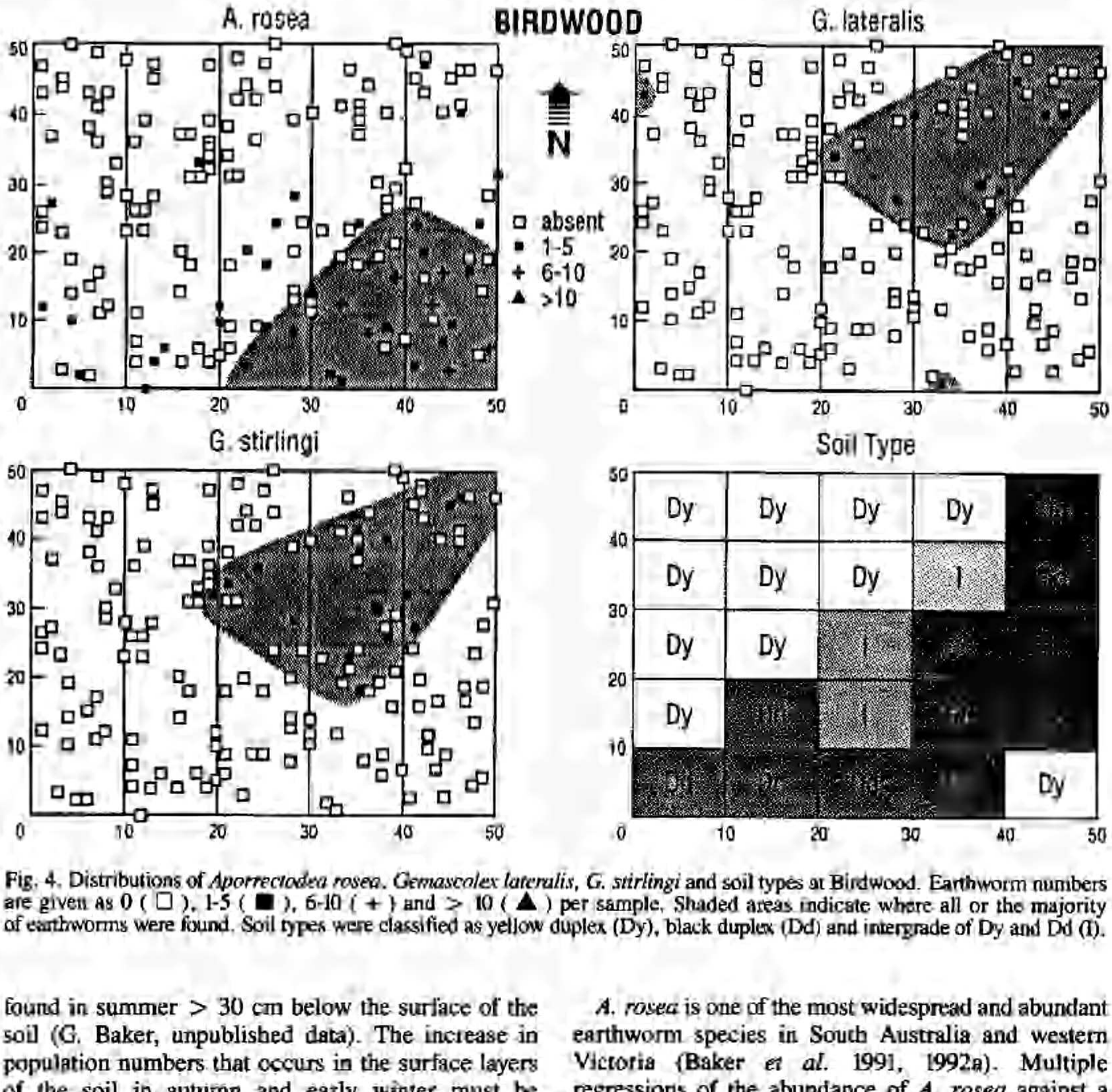

Fig. 4. Distributions of *Aporrectodea rosea*, *Gemascolex lateralis*, *G. stirlingi* and soil types at Birdwood. Earthworm numbers are given as 0 (□), 1-5 (■), 6-10 (+) and > 10 (▲) per sample. Shaded areas indicate where all or the majority of earthworms were found. Soil types were classified as yellow duplex (Dy), black duplex (Dd) and intergrade of Dy and Dd (I).

found in summer > 30 cm below the surface of the soil (G. Baker, unpublished data). The increase in population numbers that occurs in the surface layers of the soil in autumn and early winter must be explained by invasion of individuals from lower depths rather than by breeding, since no cocoons were found at that time.

Whilst pastures in the Mt Lofty Ranges are dominated by introduced lumbricids, especially *Aporrectodea* spp. (Baker *et al.* 1992a), some native megascolecids, such as *G. walkeri*, can be locally abundant and constitute a significant proportion of the total earthworm population. For example, *G. walkeri* constituted 40.1% of the total population collected at Tungkillo in 1990 (Baker *et al.* 1992b). [Most (54.8%) of the earthworms found at this site were *A. trapezoides.*] The contribution that native species make to soil structure and fertility has yet to be resolved. Experiments are currently being conducted to evaluate the role of *G. walkeri* at Tungkillo in burying surface-applied lime and offsetting soil acidity.

A. rosea is one of the most widespread and abundant earthworm species in South Australia and western Victoria (Baker *et al.* 1991, 1992a). Multiple regressions of the abundance of *A. rosea* against a variety of environmental variables have shown that soil particle size is statistically the most important regressor for sites in the Mt Lofty Ranges, as is the case for the other most common introduced species, *A. trapezoides* and *A. caliginosa* (Baker *et al.* 1992a). In general, the abundance of these earthworms increases with % clay content. Variations in soil particle size helped explain differences in the abundance of *A. trapezoides* and *A. caliginosa* at several farms including Tungkillo, Birdwood and Parawa (Baker *et al.* 1992b). They may also explain the differences in abundance reported here for *A. rosea* at Tungkillo and Birdwood. *A. rosea* was more abundant in the black duplex soil (19% clay) than in the yellow duplex soil (7% clay) at Birdwood and the uniform sand at Tungkillo (also 7% clay). The absence of *A. rosea* from Parawa (where clay content was 14%) is, however, not explained by clay content.

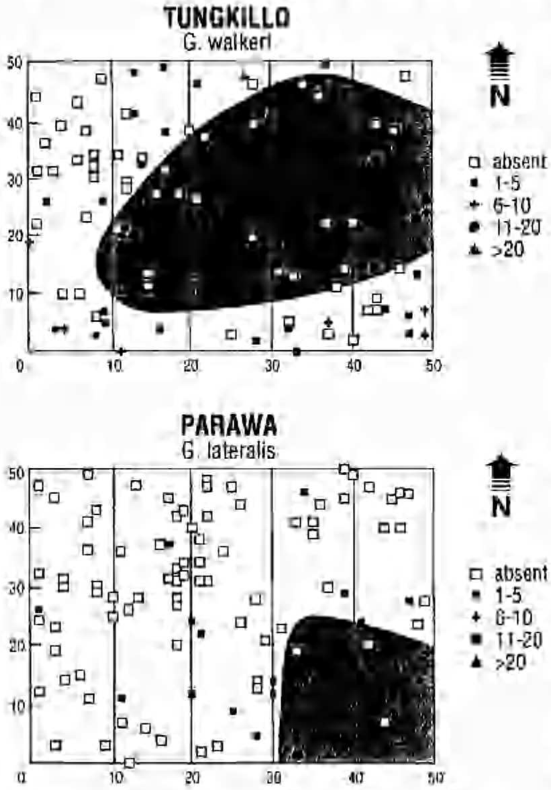

Fig. 5. Distributions of *Gemascolex walkeri* at Tungkillo and *G. lateralis* at Parawa. Earthworm numbers are given as 0 (□), 1-5 (■), 6-10 (+), 11-20 (●) and > 20 (▲) per sample. Shaded areas indicate where the majority of earthworms were found.

O. cyaneum was restricted to Parawa, the wettest site with an annual rainfall of 900 mm, compared with 575 and 750 mm at Tungkillo and Birdwood respectively. Previous surveys (Baker *et al.* 1991, 1992a) have found *O. cyaneum* at only a few sites in the highest rainfall regions of South Australia and western Victoria. There are a few records of *O. cyaneum* in Western Australia, all from the high rainfall region of the south-west (Abbott 1981). Sims & Gerard (1985) comment that *O. cyaneum* prefers moist habitats in Britain.

TABLE 2.
Gravimetric moistures (%) for soils collected at Tungkillo in March 1991.
Soils were collected at varying depths inside and outside the area in which *Gemascolex walkeri* was most abundant (see Fig. 5). Results of t tests for significant differences between data are included.

Depth (cm)	Soil Moisture Inside	Outside	t	Prob.
0-10	1.48	0.93	5.20	< 0.001
10-20	2.60	1.07	4.65	< 0.001
20-30	3.83	1.79	5.00	< 0.001
30-40	4.74	2.55	3.78	< 0.01
40-50	6.42	2.82	2.80	< 0.05

The distributions of the native species within the three sites were patchy. In some cases, possible reasons for the patchiness can be offered. For example, *G. walkeri* may be restricted by soil moisture at Tungkillo.

Baker *et al.* (1992b) reported minor levels of parasitism of *A. trapezoides* and another introduced earthworm, *Microscolex dubius*, at Tungkillo during spring by an undescribed dipteran. *G. walkeri* was more abundant than these other two species in the top 10 cm of soil at the same time, but was not parasitised.

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